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# Paleoecologic and palaeoceanographic interpretation of $\delta^{18}O$ variability in Lower Ordovician conodont species

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We agree with Suttner and Kido (2018) that if the only data available were the isotopic analyses of individual conodont taxa in the sample from basal Bed 11 of the Shallow Bay Formation (Cow Head Group), western Newfoundland, then it would not be possible to conclude from the available dataset that the species present had a tiered pelagic rather than nektobenthic lifestyle. However, our conclusion is based on an integration of the available sedimentologic constraints with the isotopic values, and thus temperature data, for individual conodont species:

1. As noted by Wheeley et al. (2018) the sedimentologic constraints are that black mudstones at the sampled location on the Cow Head slope indicate dysoxic–anoxic conditions (James and Stevens, 1986; Johnston and Barnes, 1999), that would have inhibited a benthos and nektobenthos, and is confirmed by limited evidence of burrowing and absence of infauna and epifauna. The 'background' black mudstones at Cow Head contain phosphate and chert nodules indicative of relatively cool nutrient-rich upwelling bottom waters at the time of deposition. The additional presence of black mudstone, phosphate and chert-rich clasts in the mass flow conglomerates at Cow Head (Pohler, 1994) indicates that dysoxic–anoxic conditions also extended upslope from the depositional site.

2. The isotope values derived by SIMS on individual conodont elements ('teeth') indicate that each taxon has a specific isotope range, with the difference between the coolest and warmest species being ~7–8 °C. It can be safely concluded that this isotope variation corresponds to a variation in water column temperature, as Wheeley et al. (2018) were careful to eliminate other possible sources of oxygen isotope variation, such as variations in salinity, evaporation, and freshwater input.

3. Conodonts present within the sampled grainstone were derived both by downslope transport (as noted by Suttner and Kido, 2018) and settling through the water column. The taxa do not represent inner shelf assemblages, which have a different taxonomic composition (Ji and Barnes, 1994). The warmer values observed for conodonts such as *Drepanodus planus* and *Paroistodus proteus*, cannot easily be constrained ecologically and could have been living pelagically in the mixed surface layer or on shallower parts of the (unpreserved) upper slope/shelf edge. However, given that the mid- and lower parts of the slope have indications of anoxia the only source of the cooler values observed would be for those conodont taxa to be living in the water column above the depositional locality, and not as nektobenthos. The proposed model (Wheeley et al., 2018, fig. 3), illustrates a lateral distribution of species tiered through the water column to account for both transported and locally derived conodonts to the sample.

When these data are combined, the Cow Head species within the sample can be concluded to have occupied a variety of water temperatures from the mixed surface layer (MSL) through the thermocline into relatively cooler water, and the only available habitat was the open water column. The Newfoundland data suggest a temperature offset of ~7–8 °C, using the standard temperature equations. This is consistent with temperature gradients in modern oceans from the mixed surface layer down to approximately 300 m, but the isotopic composition, and thus absolute temperatures, of Ordovician oceans remain the subject of debate (Bergmann et al. 2018).

There are a number of independent tests available for the conclusions of Wheeley et al. (2018):

1. The hypothesis of anoxia for the mid- and lower slope, was independently arrived at by James and Stevens (1986), but could be further tested using the highly reactive iron technique that has been successfully used to test independently for redox conditions in Lower Paleozoic outer shelf and slope sediments (e.g. Hammarlund *et al.* 2017).

2. As Suttner and Kido (2018) correctly observe, an additional approach would be to take a well-constrained temporal horizon and obtain the values for conodont species present from the shoreface to the foot of the slope. This work is currently being undertaken in western Newfoundland by the authors and other colleagues using the Cambrian-Ordovician boundary as a very well-constrained horizon.

We thus remain confident that by using an integrated, holistic approach to the available sedimentologic and geochemical data, that it is possible to hypothesize with some confidence that the autecology of the conodont taxa sampled in this study was one in which individual species were tiered pelagically rather than arrayed as nektobenthos along the slope.

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